

Hydraulics

3rd Year civil

First Term (2009 - 2010)

Chapter (   )

2009 - 2010

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بسم الله الرحمن الرحيم

Gradually Varied flow

تم تعريفه على انه السريان الذى تيغير عمقه تدريجياً على مسافه افقيه كبيره نسبياً .

Assumptions :

فروض السريان المتدرج

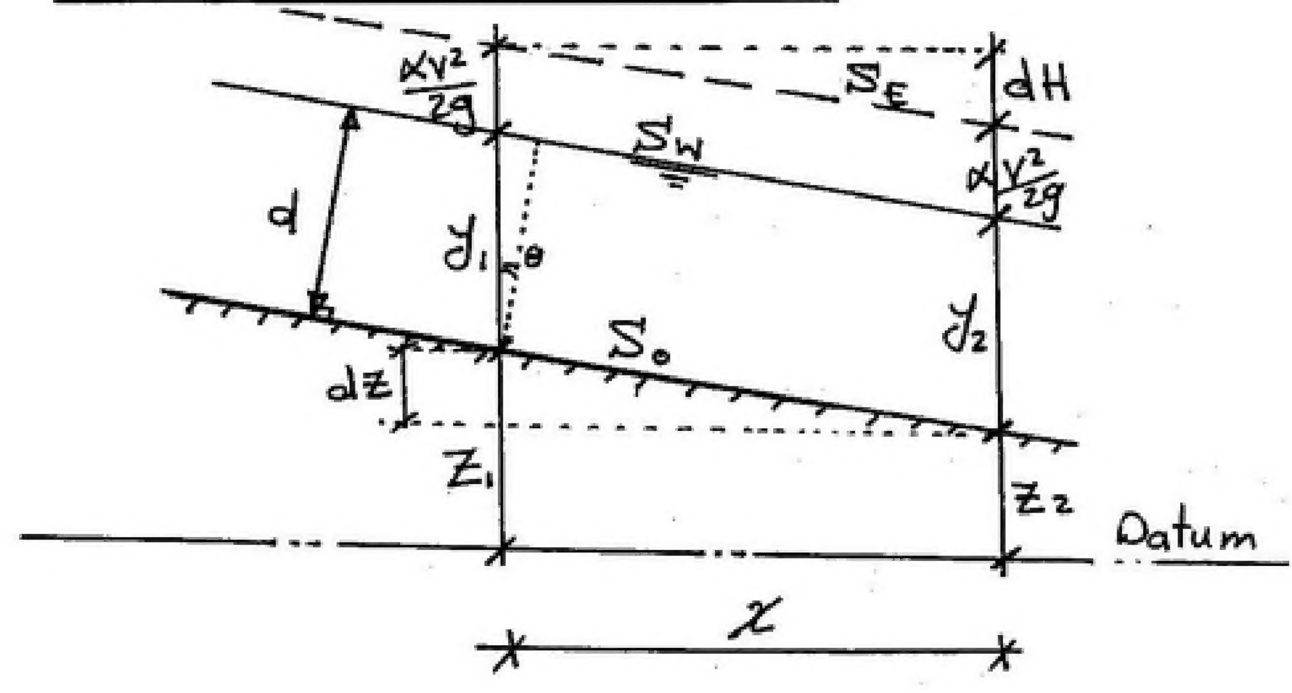
1- Flow is steady. ١- السريان مستقر .
2- stream lines are parallel. ٢- خطوط السريان متوازيه
3- slope of Canal is small. ٣- ميل القاع خفيف
4- Velocity distribution fixed. ٤- توزيع السرعه ثابت
5- Roughness Coefficient steady ٥- معامل الخشونه ثابت
6- Canal is prismatic ٦- القناه منتظمه .

Dynamic equation for G.V.F:

هى المعادلة التى يتم من خلالها دراسة السريان المتدرج (G.V.F)

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Drivision of Dynamic eqn :



$$\because \quad H = Z + d\cos\theta + \frac{\alpha v^2}{2g}$$

تتغير الطاقه الكليه على امتداد القناه بتغير المكان

$$\frac{dH}{dx} = \frac{dZ}{dx} + \frac{d}{dx}\, d\cos\theta + \frac{d}{dx}\, \frac{\alpha v^2}{2g}$$

$$\frac{dH}{dx} = -S_E$$

$$\frac{dZ}{dx} = -S_o$$

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$$-S_E = -S_o + \cos\theta \frac{d}{dx} d + \frac{d}{dx} \frac{\alpha V^2}{2g}$$

$$S_o - S_E = \cos\theta \frac{d.d}{dx} + \frac{d}{dx} \frac{\alpha V^2}{2g} \times \frac{dd}{dd}$$

$$S_o - S_E = \frac{dd}{dx} \left[\cos\theta + \frac{d}{dd} \frac{\alpha V^2}{2g} \right]$$

for small θ $\cos\theta = 1$

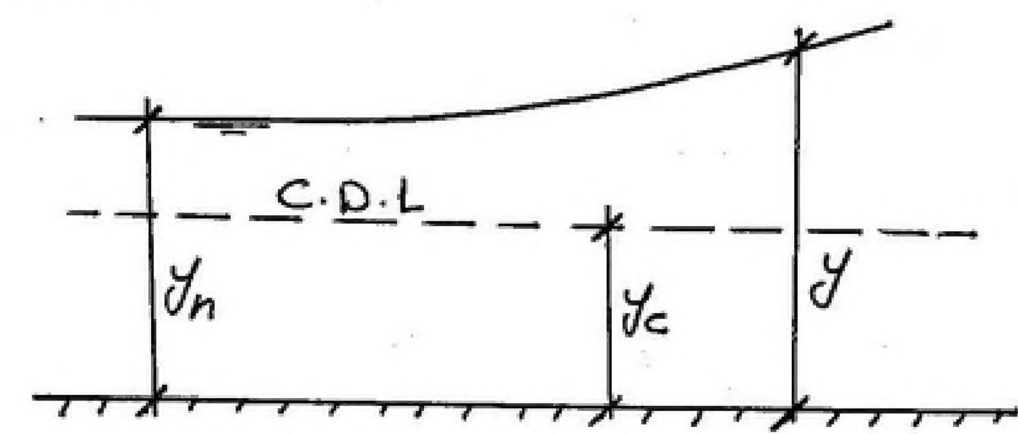
$d = y$

$$\therefore S_o - S_E = \frac{dy}{dx} \left[1 + \frac{d}{dy} \frac{\alpha V^2}{2g} \right]$$

$$\therefore \boxed{\frac{dy}{dx} = \frac{S_o - S_E}{1 + \frac{d}{dy} \frac{\alpha V^2}{2g}}}$$ dynamic equation

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Y_c : Critical water depth العمق الحرج للماء

Y_n : normal water depth العمق الطبيعي بدون تغير

Y : water depth in variation العمق في منطقة التغير

ملحوظة

Y_n يمكن أن يكون أكبر من (Y_c) أو أقل من (Y_c)

حسب حالة السريان

$Y_n < Y_c$ super critical flow

$Y_n > Y_c$ sub-critical flow

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Forms of dynamic eqn:

[1] Section factor (Z)

$$Z = A\sqrt{y_h} = A\sqrt{\frac{A}{T}} = \sqrt{\frac{A^3}{T}}$$

$$\because \frac{dy}{dx} = \frac{S_o - S_E}{1 + \frac{d}{dy}\frac{\alpha V^2}{2g}}$$

for $\alpha = 1$

$$\frac{d}{dy}\frac{V^2}{2g} = \frac{d}{dy}\frac{Q^2}{2gA^2}$$

$$= -\frac{2Q^2}{2gA^3}\frac{dA}{dy}$$

$$\because \frac{dA}{dy} = T$$

$$\therefore \frac{d}{dy}\frac{V^2}{2g} = -\underbrace{\frac{Q^2}{g}}_{Z_c^2}\;\underbrace{\frac{T}{A^3}}_{\frac{1}{Z^2}}$$

$$\therefore \frac{d}{dy}\frac{V^2}{2g} = -\left(\frac{Z_c}{Z}\right)^2$$

$$\therefore \boxed{\frac{dy}{dx} = \frac{S_o - S_E}{1 - \left(\frac{Z_c}{Z}\right)^2}}$$

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2 Conveyance factor (K):

$$Q = \frac{1}{n} \cdot \frac{A^{5/3}}{P^{2/3}} \cdot S_o^{1/2} = \frac{1}{n} \cdot A \cdot R^{2/3} \cdot S^{1/2}$$

معامل النقل $K = \frac{1}{n} \cdot A \cdot R^{2/3}$

$$\boxed{Q = K \cdot S_o^{1/2}}$$

$$\because \frac{S_E}{S_o} = \left(\frac{K_n}{K}\right)^2$$

$$\because \frac{dy}{dx} = \frac{S_o - S_E}{1 + \frac{d}{dy}\frac{V^2}{2g}}$$

$$\frac{dy}{dx} = \frac{S_o\left(1 - \frac{S_E}{S_o}\right)}{1 - \left(\frac{Z_c}{Z}\right)^2}$$

$$\therefore \boxed{\frac{dy}{dx} = \frac{S_o * \left(1 - (K_n/K)^2\right)}{1 - \left(\frac{Z_c}{Z}\right)^2}}$$

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3 Kinetic energy factor (λ):

$$\lambda = (F_n)^2 = \frac{V^2}{g \cdot y}$$

$$\frac{dy}{dx} \doteq \frac{S_o - S_E}{1 + \frac{d}{dy}\frac{V^2}{2g}}$$

$$\because \frac{d}{dy}\frac{V^2}{2g} = \frac{-Q^2}{g} \cdot \frac{T}{A^3}$$

$$= - \frac{V^2 \cdot T}{g \cdot A} = -\frac{V^2}{g \cdot y_h}$$

$$\therefore \frac{d}{dy}\frac{V^2}{2g} = -\lambda = -F_n^2$$

$$\therefore \boxed{\frac{dy}{dx} = \frac{S_o - S_E}{1 - \lambda}}$$

4 Critical water depth (y_c):

$$\boxed{\frac{dy}{dx} = \frac{S_o - S_E}{1 - (y_c/y)^3}}$$

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5 Normal water depth (y_n):

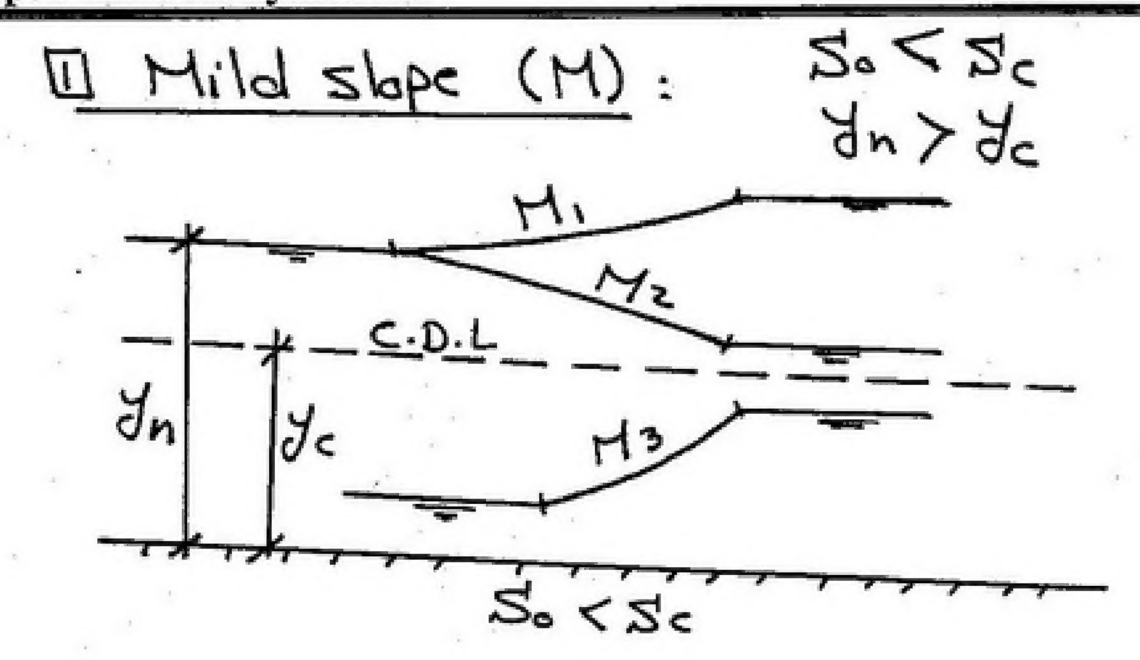
$$\frac{dy}{dx} = S_o \frac{1-(y_n/y)^3}{1-(y_c/y)^3}$$

Solution of G.V.F:

وجد أنه بحل المعادلات السابقة ورسمها أن هناك
١٢ منحنى يمكن الحصول عليها وتم تصنيف هذه المنحنيات
تبعاً لميل القاع وعلاقته بالميل الحرج (S_c) أى

1. **Mild slope (M):**
   $S_o < S_c$, $y_n > y_c$
2. **steep slope (S):**
   $S_o > S_c$, $y_n < y_c$
3. **Critical slope (C):**
   $S_o = S_c$, $y_n = y_c$
4. **Horizontal slope (H):**
   $S_o = 0$, $y_n > y_c$
5. **Adverse slope (A):**
   $S_o > 0$ $y_n > y_c$

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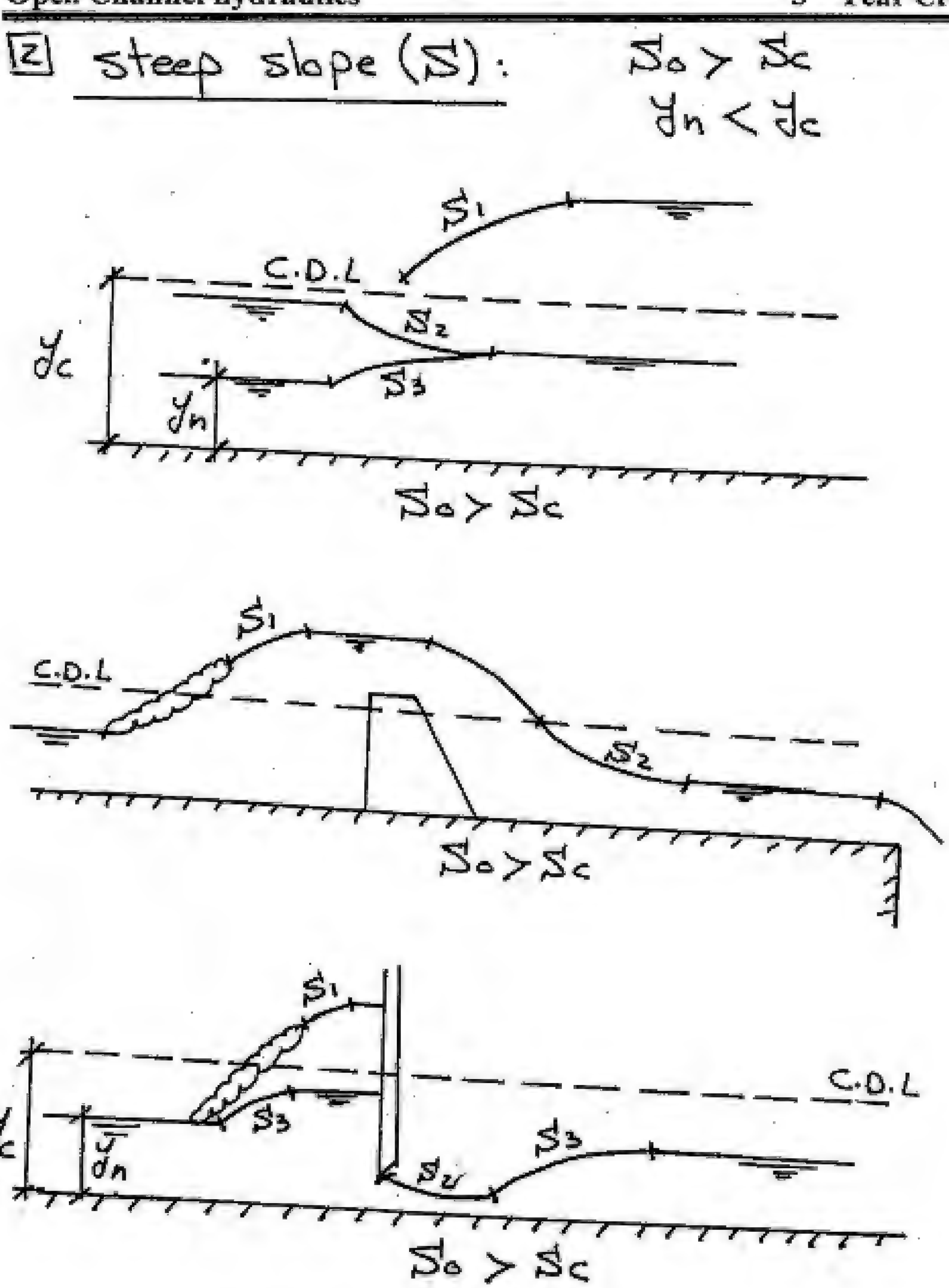


M1
M2
C.D.L
M2
M3
So < Sc

M1
yn
yc
C.D.L
M3
So < Sc

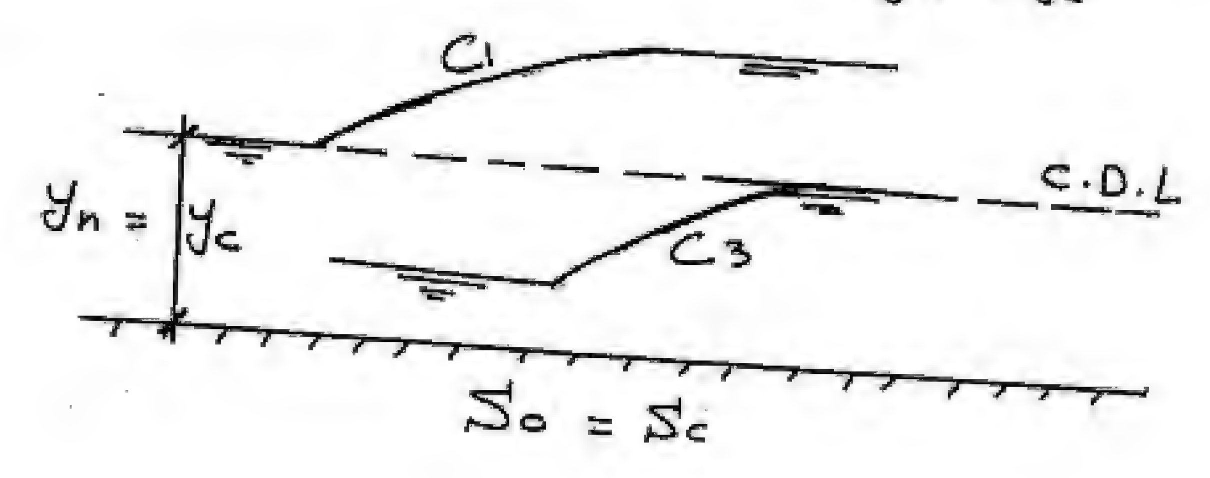
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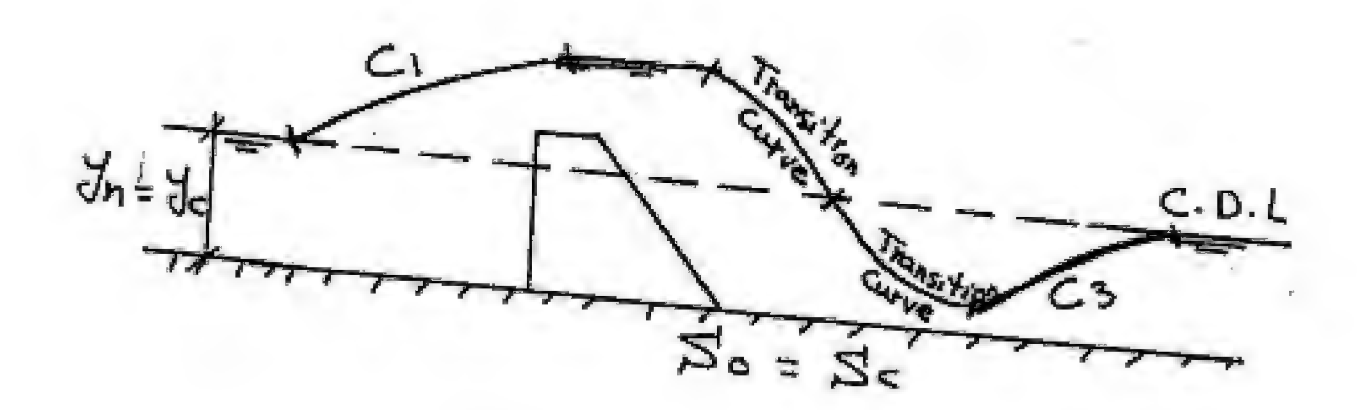
2 steep slope (S): $S_o > S_c$
$y_n < y_c$

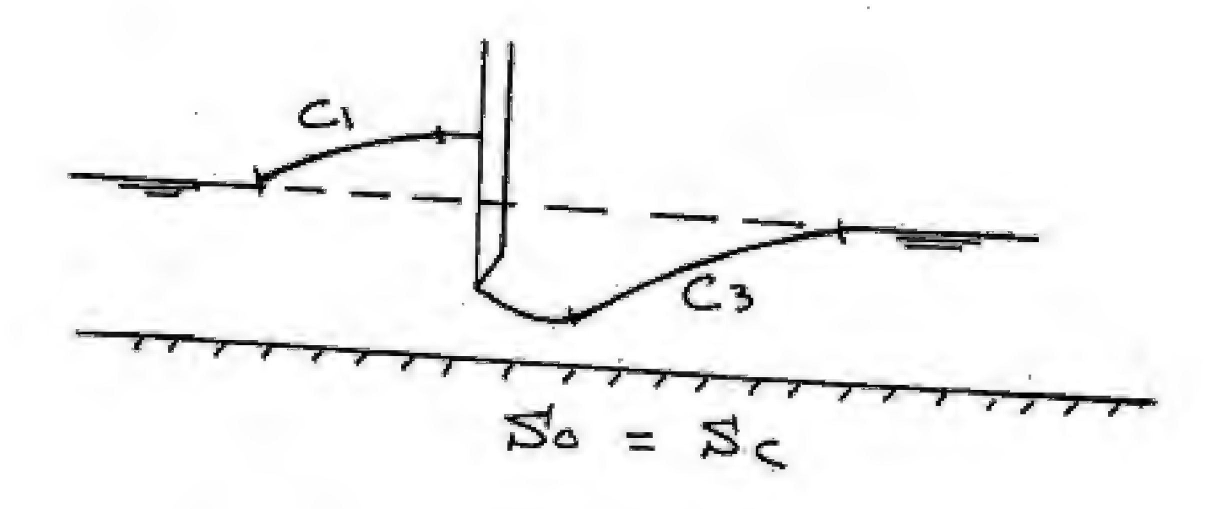


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3 Critical slope (C) : $S_o = S_c$
$y_n = y_c$

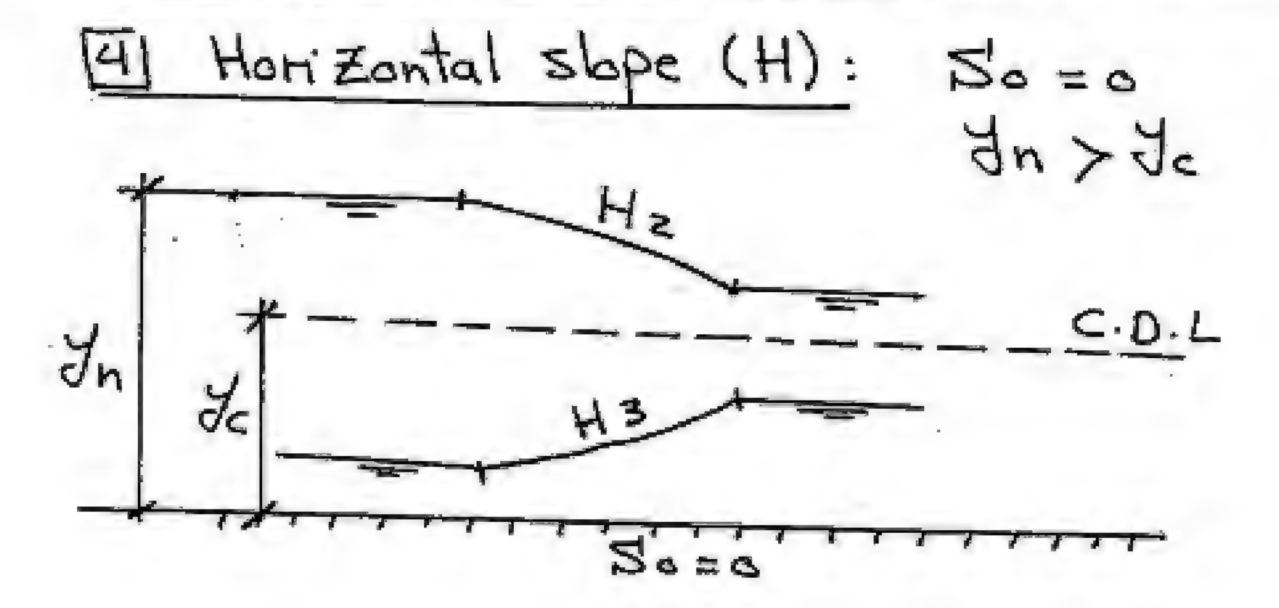


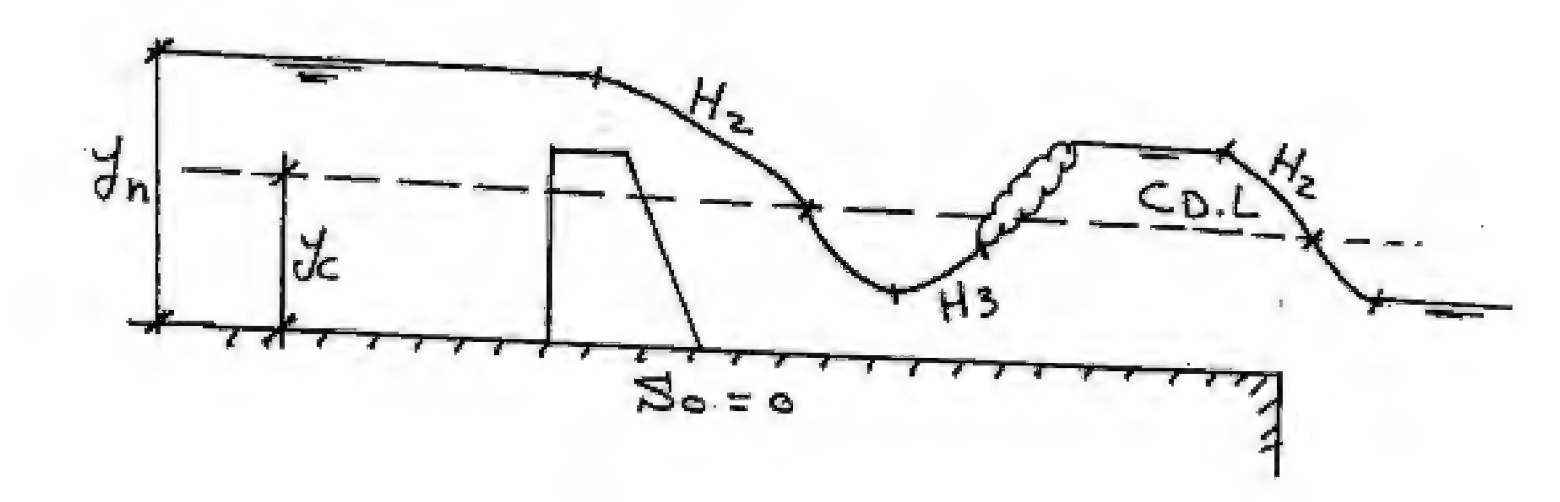


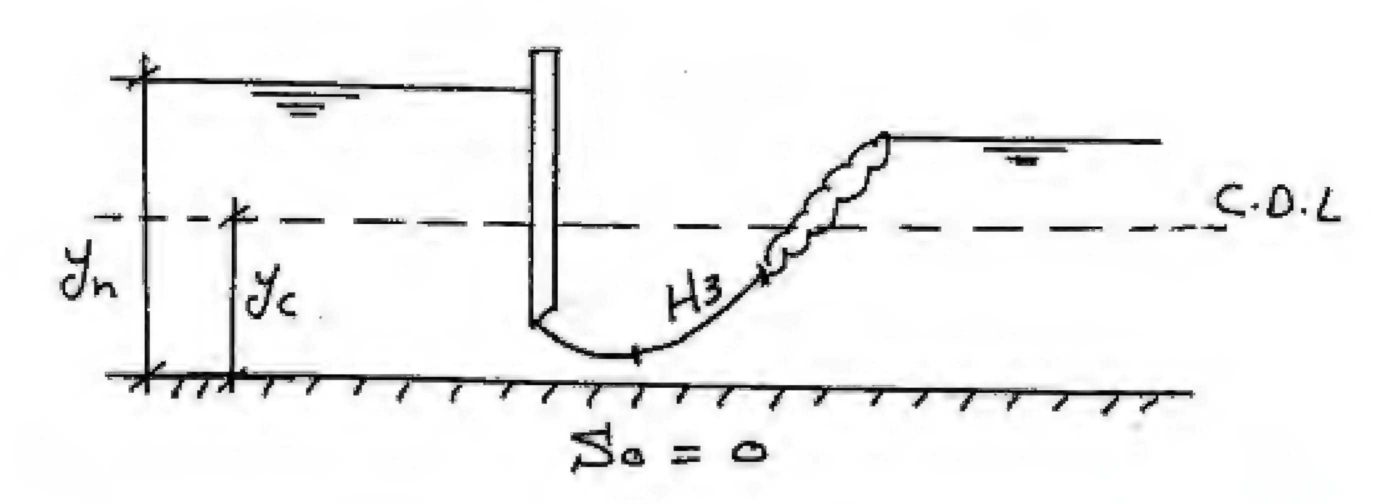


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4 Horizontal slope (H): $S_o = 0$
$y_n > y_c$





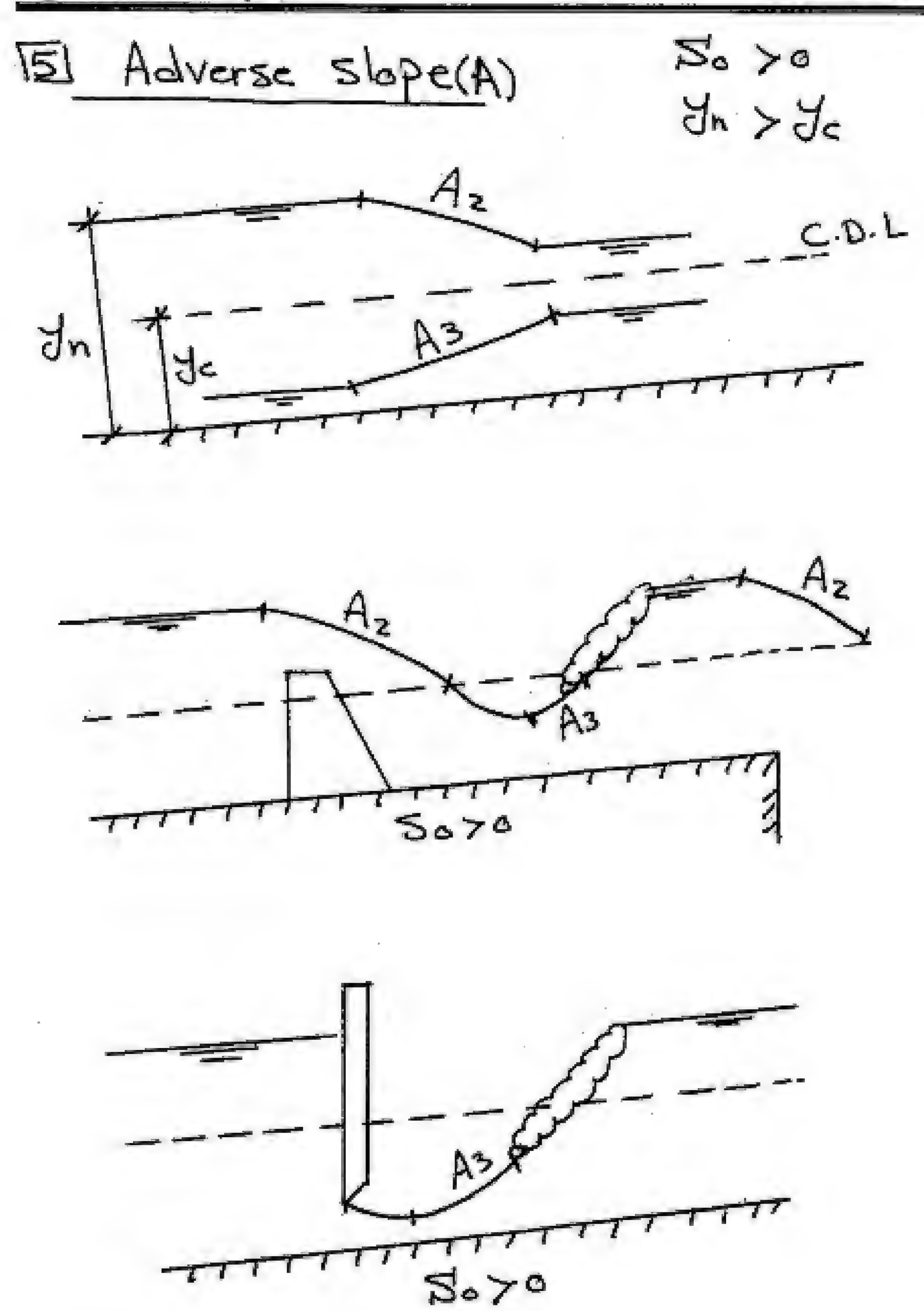


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5 Adverse slope(A)

$S_o > 0$

$y_n > y_c$



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Computation of G.V.F:

يقصد بحساب السريان المتدرج هو ايجاد نوع المنحنى المتكون وكذلك ايجاد طول المنحنى الذى يبدأ بعمق معين وينتهى عند عمق آخر .

Method of Computations:

طرق الحساب

1 - graphical integration method.
2 - direct " ".
3 - direct step method. ←
4 - standard step.
5 - Bresse function.
6 - Grimn's method.
7 - Ezra method.

وسوف يتم الاهتمام بطريقة واحدة فقط وهى

Direct step method

$$\Delta X = \frac{E_2 - E_1}{S_o - (S_E)_{average}} = \frac{\Delta E}{\Delta S}$$

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Direct step method:

$$\Delta X = \frac{\Delta E}{\Delta S} = \frac{E_2 - E_1}{S_o - (S_E)_{ave.}}$$

يتم الحل في صورة جدول كالآتي

	العمق	المساحة	السرعة	الطاقة		المحيط	A/P					
Sec.	y	A	V	E	ΔE	P	R	S_E	$S_{E\,av.}$	ΔS	ΔX	$\Sigma \Delta X$
1												
2												
3												

$$Q = \left(\frac{1}{n} \cdot R^{2/3} \cdot S_E^{1/2}\right) \times A$$

$$\therefore \boxed{S_E = \frac{n^2 \cdot V^2}{R^{4/3}}}$$

S_o: ميل قاع القناة

S_E: ميل خط الطاقة

$$R = \frac{A}{P}$$

$$E = y + \frac{V^2}{2g}$$

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١- المنحنيات M_3 ، A_3 ، H_3 يتكونوا قبل حدوث القفزه الهيدروليكيه.

٢- المنحنى S_1 يتكون بعد حدوث القفزه الهيدروليكيه.

٣- المنحنيات C_1 ، C_3 لا يحدث معهم قفزه هيدروليكيه.

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Gradually Varied Flow

1- A sluice gate is installed in a rectangular canal of bed width 5.00 m, with normal water depth of 1.50 m , (n = 0.02) , if the bed slope of the canal is $S = 8.33 \times 10^{-4}$, and passing a discharge of 21.60 m^3/sec, it is required to

a- Name and draw the water profile before the gate

b- Fid the length of the water profile U.S. the gate

Note the water depth just U.S gate 3.5 m

2- A dam is constructed across of trapezoidal canal of 25.00m bed width , with side slope 2:1, bed slope of 12×10^{-5} and Manning 1/n = 40, the canal carries a discharge of 15000 cubic meter / min, the depth just upstream the dame 10.00m a GVF profile is formed US the dam, practically speaking the profile started at a depth of 1.10 of the normal water depth, it is required to

a- Draw and name the profile

b- Find the length of the profile

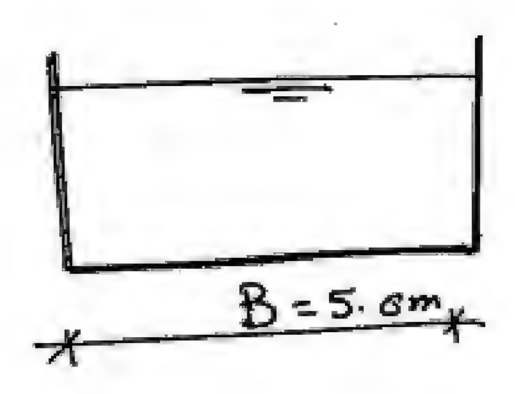
3- A trapezoidal canal of bed width of 4.00m with side slope of 1:1 and bottom slope of 0.000016, and carries a discharge of 2.90 m^3/sec, and n=0.02 determine the distance required to change the flow depth from 0.90m to 0.50m using direct step method (only three steps are needed), what is the type of the profile by letter and number.

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Q(1):

- $y_n = 1.50 m$
- $n = 0.02$
- $S_o = 8.33 \times 10^{-4}$
- $Q = 21.60 \; m^3/s'$



Req.:

a - Name and draw the Profile

b - Length of profile

Sol.:

$$\because \; y_c = \sqrt[3]{q^2/g}$$

$$q = \frac{Q}{b} = \frac{21.6}{5} = 4.32 \; m^3/s'/m'$$

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$$y_c = \sqrt[3]{\frac{(4.32)^2}{9.81}} = 1.23 \text{ m}$$

$$\because \ y_n > y_c$$

$$S_o < S_c \quad (\text{Mild})$$

1 2 M1 3 4

1.50 m

3.50 m

X

(b) <u>by using direct step method</u>

$$\because \ \Delta X = \frac{\Delta E}{\Delta S}$$

$$= \frac{E_2 - E_1}{S_o - (S_e)_{av.}}$$

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Rectangular section: $b = 5$, depth y

$Q = 21.6\ m^3/s$, $E = y + \frac{V^2}{2g}$

Sec No	y	A ($b \cdot y$)	V (Q/A)	E	ΔE	P ($b+2y$)	R (A/P)	S_E	$S_{E\,av.}$	ΔS ($S_o - S_{E\,av.}$)	Δx
1	1.50	7.5	2.88	1.92		8	0.94	3.6×10^{-3}			
					0.31				2.61×10^{-3}	[illegible]	172.2
2	2.0	10	2.16	2.23		9.0	1.11	1.62×10^{-3}			
					0.42				1.26×10^{-3}	0.00043	976.7
3	2.5	12.5	1.73	2.65		10.0	1.25	8.9×10^{-4}			
					0.95				6.3×10^{-4}	0.00021	4523.8
4	3.5	17.5	1.23	3.66		12	1.46	3.7×10^{-4}			

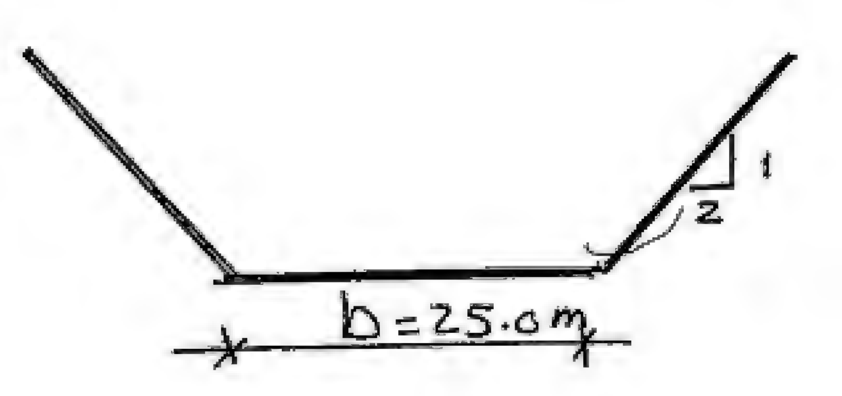
Total: 5672.7 m

$$S_E = \frac{n^2 \times V^2}{R^{4/3}}$$

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Q(2) :

$S_o = 12 \times 10^{-5}$



$\frac{1}{n} = 40$

$Q = 15000 \ m^3/min.$

$y_{u.s\ dam} = 10.0 \ m$

Req. : - draw and name
- Length

Sol. : $\because Q = \frac{1}{n} \cdot \frac{A^{5/3}}{P^{2/3}} \cdot S^{1/2}$

$Q = \frac{15000}{60} = \quad m^3/S$
$= 250 \ m^3/S$

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$- A = (b + Zy)\,y$

$= (25 + 2 \times y)\,y = (25 + 2y)\,y$

$- P = b + 2y\sqrt{1 + Z^2}$

$= 25 + 2y\sqrt{1 + 2^2}$

$= 25 + 4.47y$

$$\therefore 250 = \frac{1}{0.025} \times \frac{[(25 + 2y)y]^{5/3}}{[25 + 4.47y]^{2/3}} \times (12 \times 10^{-5})^{1/2}$$

$$570.5 = \frac{[(25 + 2y)y]^{5/3}}{[25 + 4.47y]^{2/3}} \quad \text{by trial}$$

y_n	4	4.5	5.5	6.00	
R.H.S	279.3	345.4	498.4	585.6	

$y_n \cong 5.80\,m$ تقريباً

$\because T = b + 2Zy = 25 + 4y_c$

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$$\because \quad \frac{Q^2}{g} = \frac{A^3}{T}$$

$$\frac{(250)^2}{9.81} = \frac{\left[(25+2y_c)y_c\right]^3}{(25+4y_c)}$$

$$6371.0 = \frac{\left[25y_c + 2y_c^2\right]^3}{\left[25 + 4y_c\right]} \quad \text{by trial}$$

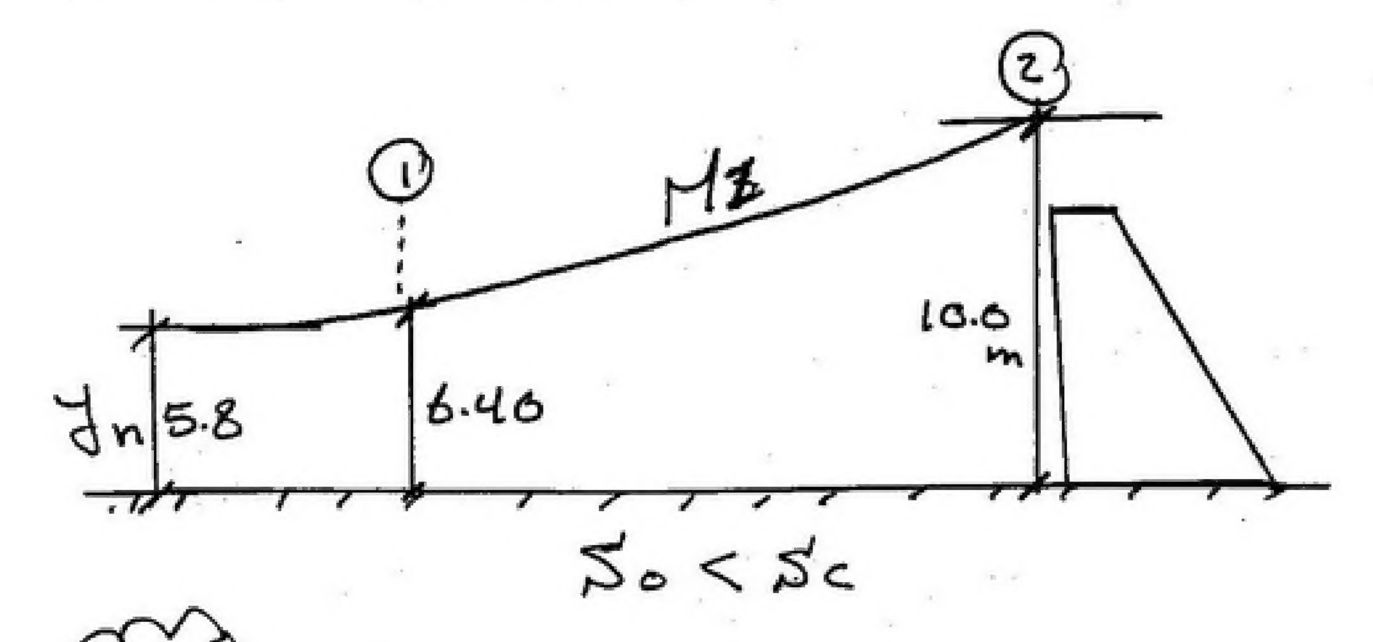
y_c	2.0	2.10				
R.H.S	5912.	6903				

$$y_c \simeq 2.05 \text{ m}$$

$$\because \quad y_n > y_c$$

$$\therefore \quad S_o < S_c \quad \text{(Mild)}$$

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y at start of Curve $= 1.10\, y_n$

$= 1.10 \times 5.80$

$= 6.40\,m$

by using direct step method

$$\because \Delta X = \frac{\Delta E}{\Delta S}$$

$$\Delta E = E_2 - E_1$$

$$\Delta S = S_o - S_{E\,av.}$$

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$A = (b + zy)y = (25 + 2y)y$

$Q = 250 \ m^3/s$

$E = y + V^2/2g$

$V = Q/A$

$P = 25 + 4.47y$

$R = A/P$

b = 25 m, side slope 2 : 1

sec. No	y	A	V	E	ΔE	P	R	S_E	$S_{E\,av.}$	ΔS	ΔX
1	6.4	242	1.03	6.45		53.6	4.52	8.9×10^{-5}			
					3.57				5.35×10^{-5}	6.65×10^{-5}	53684.2 m
2	10.0	450	0.60	10.02		69.7	6.46	1.8×10^{-5}			53.68 Km

$$S_E = \frac{n^2 \cdot V^2}{R^{4/3}} \quad , \quad n = 0.025$$

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